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Online Monitoring of Shrimp Aquaculture in Bangka Island Using Wireless Sensor Network

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***Abstract*— In this paper, it will be described the design and realization of online water quality monitoring system based on wireless sensor network (WSN). The new system has been implemented specifically to monitor parameters Dissolved Oxygen (DO), pH and temperature in one spot shrimp aquaculture in Bangka island. The aim was to create suitable water conditions for shrimp aquaculture and save the cost of energy consumption using an automated aeration system, by maintaining the value of the DO above 5 mg/L. On the other hand, water quality data collected from sensor measurements are sent to a data logger using WSN, and then the data is sent to a data center using cellular network (GPRS) such that this data can be viewed using the website. The experimental results show that the system has great prospects and can be used for shrimp aquaculture by providing information that is relevant and timely. The resulting data the collection can be used for research and analysis.**

***Keywords*— Automatic aeration; GPRS; sensors; shrimp aquaculture; water quality; wireless sensor network**

I. INTRODUCTION

In developing countries such as Indonesia, managing water resources has become a fundamental issue that has been discussed seriously by the government and public organisations over the past decade. The aim was to ensure sustainability of water resources for future generation. Water resource management not only concerns about water conservation but also includes providing information about water quality, that should be accessible by the public so that early preparation can be taken by those affected by degradation in water condition [1]. Such information can be provided only by a well-planned water quality measuring network applied to specific uses such as drinking [2], industrial [3], agriculture [4], aquaculture [5], etc. The main problem in realising a network of the water quality monitoring system in island countries like Indonesia is related to geographical location separating the water resources and the management.

In the world of aquaculture, water quality control is needed to maintain the optimum conditions for the health and growth of the aquatic lives preserved and is one of the factors determining every successful aquaculture [6]. Although there are many parameters affecting water quality in shrimp aquaculture, only three are considered the most important parameters, i.e., Dissolved Oxygen (DO), pH and temperature [7]. For the good health of the shrimp, DO optimal value for cultivation is between 4-7,5ppm. pH indicates the level of acidity or alkaline water. Thus the optimum pH value for the life of the shrimp is from 7.5-8.5, while an ideal temperature value for shrimp cultivation is 25-31^{0}C [8].

Controlling the water quality in shrimp aquaculture is done conventionally by taking water samples and then analyze it in the laboratory [9]. With more advanced techniques, water quality measurements can be done using hand-held instruments regularly. Both of these methods have drawbacks such as impractical, expensive labor and the high possibility of human error [10]. In addition, to maintain a high DO in shrimp aquaculture, aeration systems using many paddle wheel aerators are common, thus requiring high operational costs [11]. To solve the above problem, WSN technology can be applied in monitoring water quality to provide the best approach by online data acquisition, transmission, and processing of data [12]. The main advantage of WSN is cheap in the implementation and maintenance because the setup requires no fixed infrastructure, low power and can be installed at any remote place [13].

Previous works demonstrating the use of WSN for water quality monitoring have been shown [14] to monitor Lake Victoria Basin. The system, consisting of a sensor node, a gateway node, and software application, was capable of delivering four water quality parameters (temperature, DO, pH, and conductivity) to relevant stakeholders using web-based and mobile phone platforms. Similarly, [15] developed a WSN suitable for complex and large-scale water resource monitoring, whereas [16] showed the WSN design suitable for a long-term application in an aqueous environment. In most recent WSN architectures, the trend has been using a custom data logging system to acquire environmental quality data and transmitting it to a remote data server, by which then the data will be distributed to a website or mobile phone devices [17], [18].

An online monitoring system for water quality based on WSN incorporating automated aeration systems have been designed and implemented in one of the centers of shrimp aquaculture in Bangka island (PT. Merdeka Sarana Usaha, Jln. Pasir Padi Kelurahan Ketapang, Bukit Intan Pangkalpinang). This system allows not only the collection of water quality parameters that can be viewed through a website (www.ppet.org/water), Twitter (@wqmppet) and Telegram Messenger Notification (WhatsApp) [19], but also perform automatic aeration on a paddle wheel aerator for cost savings of energy consumption, where aeration is done only when the value of the DO drops below a threshold value. The advantage is not only improving yields and quality of shrimp aquaculture today but also provide important data for the future development of the aquaculture. System design, realization, and operation will be explained in the following sections**.**

II. Material and Method

The system has been designed on a modular basis to simplify the treatment and modification. The system consists of sensor modules, data loggers, web server, and aeration control. The water quality data collected at the installation location from the sensor module. The data from the sensor module is then transmitted to the data logger using WSN. The data logger then processed display and transmit the data to the server using GPRS protocols. There are some features available in this application, and the process of sending data from the server to the data logger and twitter application is done periodically every 10 minutes and can reset itself every 1 hour. The basic concept of online water quality monitoring system based on WSN for shrimp aquaculture is shown in Fig. 1.

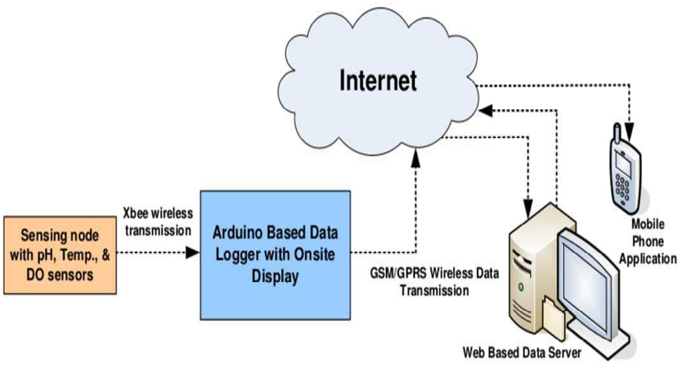

Fig. 1 The concept of online water quality monitoring

A. Sensor Module

Sensor module has the task to read the water quality data in the form of oxygen content and acidity in shrimp aquaculture. The sensor module consists of sensor components, i.e., pH, DO (Atlas Scientific), a temperature sensor (DS18B20 MAXIM), Arduino UNO, and XBee Pro. The components used for the microcontroller is Arduino UNO with the task to retrieve the sensor data if there is a request from the data logger module. Communication between the sensor module with data logger module is done wirelessly using the ZigBee protocol that works at a frequency of 2.4 GHz. Access to the data from the Arduino UNO to the XBee Pro is done using serial communication. The Arduino Uno program block diagram, flowchart, and sensor module can be seen in Fig. 2, Fig. 3 and Fig. 4.

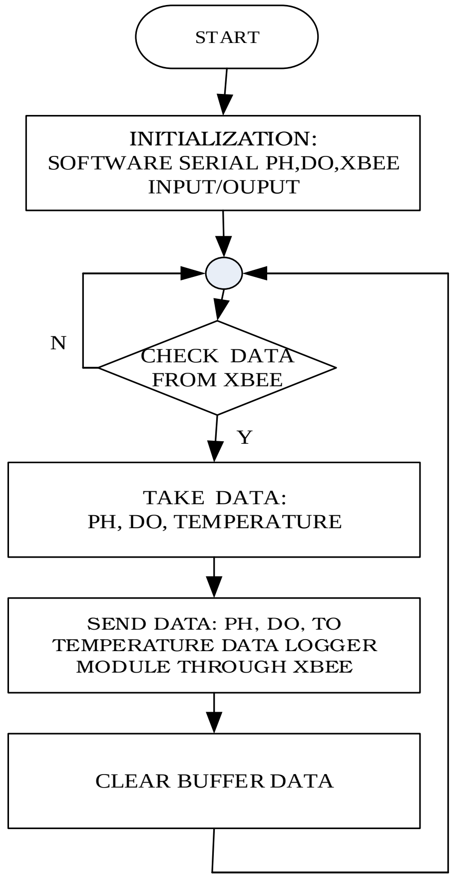

Fig. 2 Flowchart program Arduino Uno

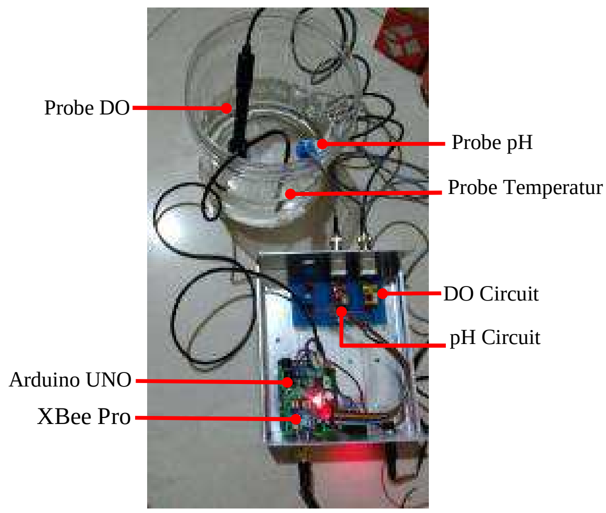

Fig. 3 Block diagram of the sensor module

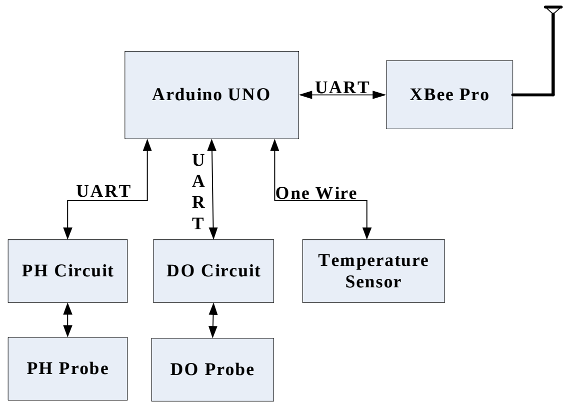

Fig. 4 Sensor module

B. Data Logger Module

The module consists of an Arduino Mega, XBee pro, GPRS/GSM modem, and LCD 16x2. In this module, it also features a relay output which is connected to the control module for the automatic aeration system. The On/Off conditions of paddle wheel were determined by setting the max/min threshold. The value of the max/min threshold refers to the value of the DO, and usually, for every shrimp aquaculture, this value is specifically dependent on the area. In this system, the min value for DO (min threshold) is set at 4.0 while the max value for DO (max threshold) is set at 5.0. Communication between Arduino mega board with XBee and GPRS/GSM module is done serially with a baud rate of 38400, 8 data bits, one stop bit and the parity none, while communication with the RTC module is done using I2C protocol. Block diagrams and installation of data logger module can be seen in the Fig. 5, Fig. 6 and Fig. 7

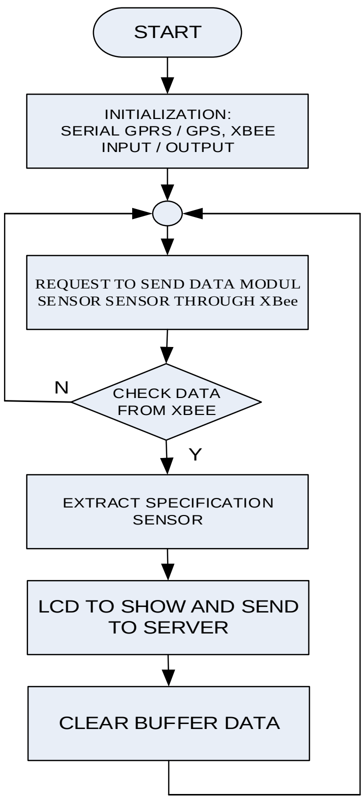

Fig. 5 Flowchart program data logger module

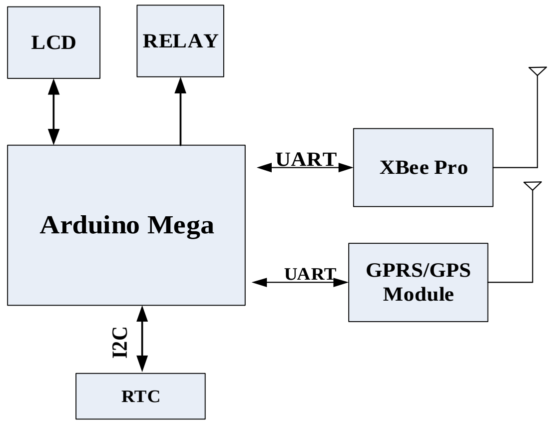

Fig. 6 Block diagram data logger module

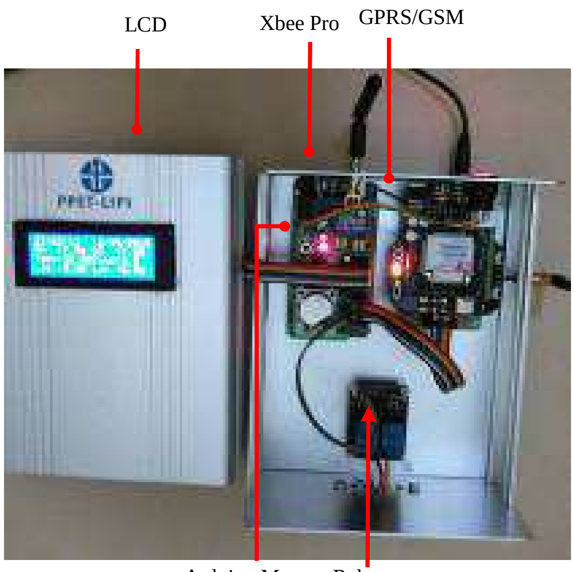

Fig. 7 Data logger module

C. Aeration Control Module

One of the main features of this system is automated aeration method that uses aeration control module. The module is designed to reduce the high energy consumption of electricity due to excessive use of the aeration system. As can be seen in Fig. 8, the shrimp pond aeration system usually consists of 8 paddle wheel aerators, and in critical condition, all turbines will be operated continuously during the cultivation period. So the idea is to selectively operate the paddle wheel aerators, activating them in a non-continuous operation, depending on the value of water DO. It is known that during a sunny day, usually DO is very high value on shrimp aquaculture (above average 8). So operating water wheel aerators in these conditions will not have a significant impact in increasing the value of the DO. With aeration system operates only at night, or when the DO drops below a certain level would obviously save electrical energy consumption. It is estimated that at least 30% electrical energy savings can be achieved if the aeration system is operated under these conditions. The aeration control module can be seen in the Fig. 8.

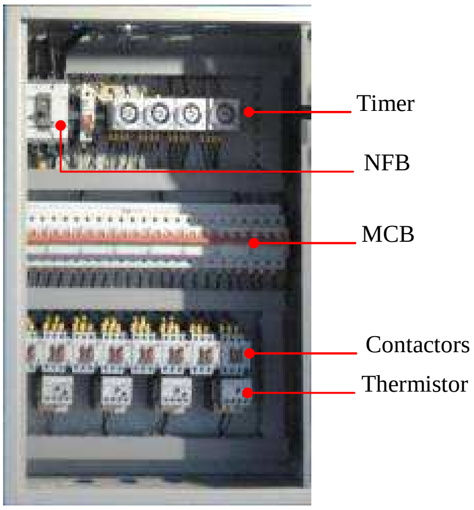

Fig. 8 Aeration control module

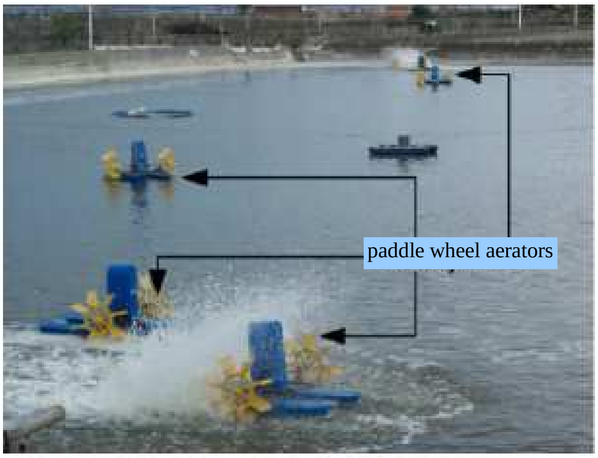

Fig. 9 Aeration system consisting of many paddle wheel aerators operated automatically based on the DO value of the water

D. *Web Server*

The online monitoring system is designed so that the sensor data at any point / station can be seen online via the website by a user as long as connected to the Internet either through a laptop, PC or other mobile devices. The web server will display sensor data via the web client and store sensor data in the database system so that the data can be stored well over time. The database management system is very necessary for data processing, for data display in graphical format, and for analysing the recorded data sometimes in the future. In this system the database used is MySQL. To perform queries (insert, update, delete, etc.) to the MySQL database, the web-based programming language used is PHP. The website for the online monitoring system and the main components have been designed in a form to make it easier to fit the screen size of the web client or browser used by a user using a laptop, PC or on mobile devices. The web server in this system is designed with several features that display data in graphs and tables, and export data in Excel, image and pdf formats. Additionally, it has a user access management so that different user has different access rights.

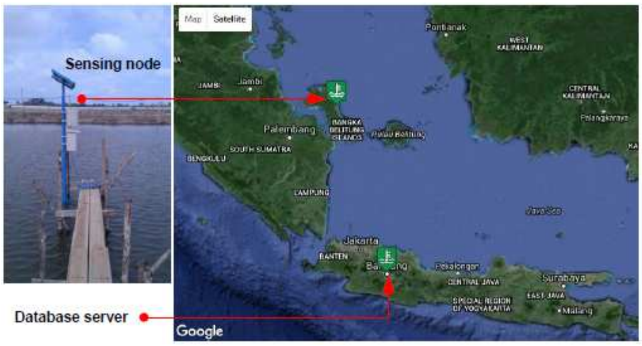

Fig. 10 Location of the sensing node in Bangka island and the database server in Bandung, West Java

III. Results And Discussion

The system has been implemented to measure the water quality parameters of shrimp aquaculture located in Bangka island, and the database server is located in Bandung, West Java. As can be seen in Fig. 10, the sensing node was installed in the middle of a shrimp pond, using a 50 W solar panel as the power source. The data logger was placed on the side of the pond within 20 m distance from the sensing node. Since its first installation in November 2015, the system has been continuously sending data to the database server without any significant interruption, except during maintenance period. This means that the system has proved itself suitable for a long-term, outdoor monitoring application.

In Fig. 11, it can be seen the website view of the water quality data which is updated every 10 minutes interval. This information is accessible to the public from http://www.ppet.lipi.go.id/water/home.php; however, for the historical and graphical display of the data, it requires login access to the system. In Fig. 11, the screenshot view of the data as appeared on a mobile phone's Whatapps application is shown. The data on the mobile phone application was also updated every 10 minutes. Several mobile phone numbers have been selected belonging to the management of the aquaculture business to receive information of the water quality parameters.

Fig. 11 Screenshot of the website on mobile devices

In Fig. 12, it is shown the characteristics of DO and pH conditions of the shrimp pond water on January 15, 2015. As can be seen, the DO value will reach the highest peak around 6.0 mg / L at 12.00 pm and will decrease in the afternoon. As for the pH value, it is not much change between 7.0 - 8.0 for the whole day. The sensor data is also sent to Twitter and other social media application such as Telegram Messenger Notification, as shown in Fig. 13.

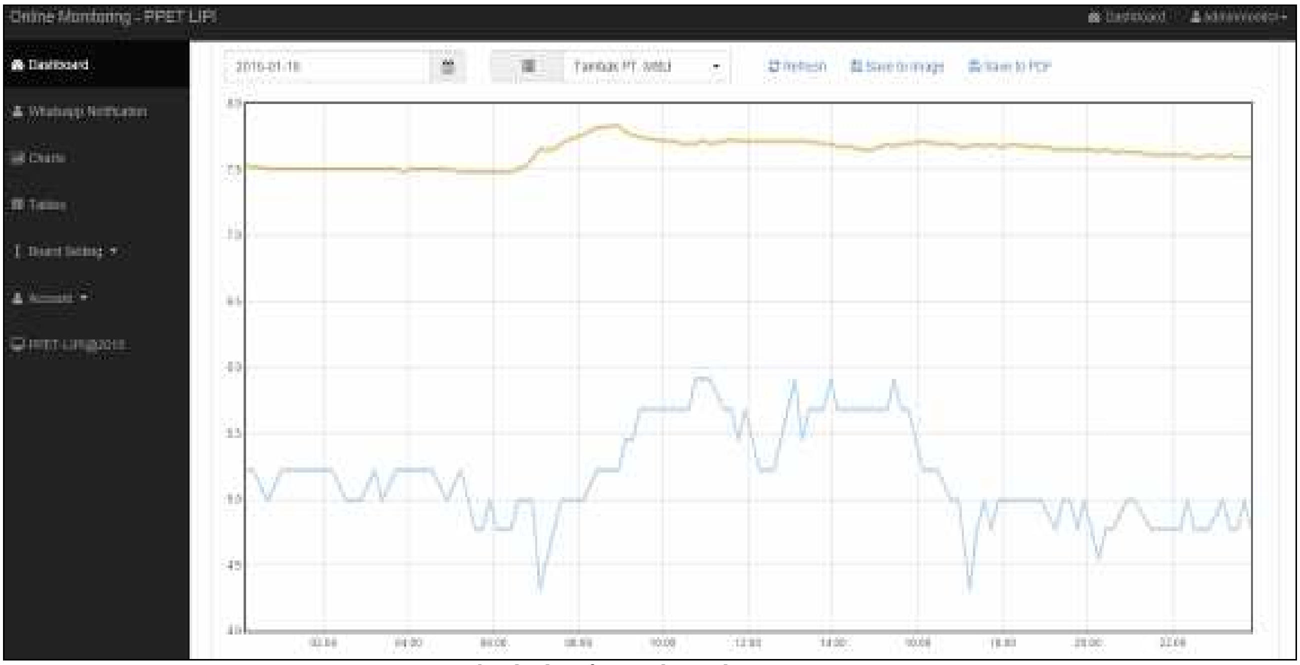

Fig. 12 Graphic display of DO and pH values on January 18, 2015

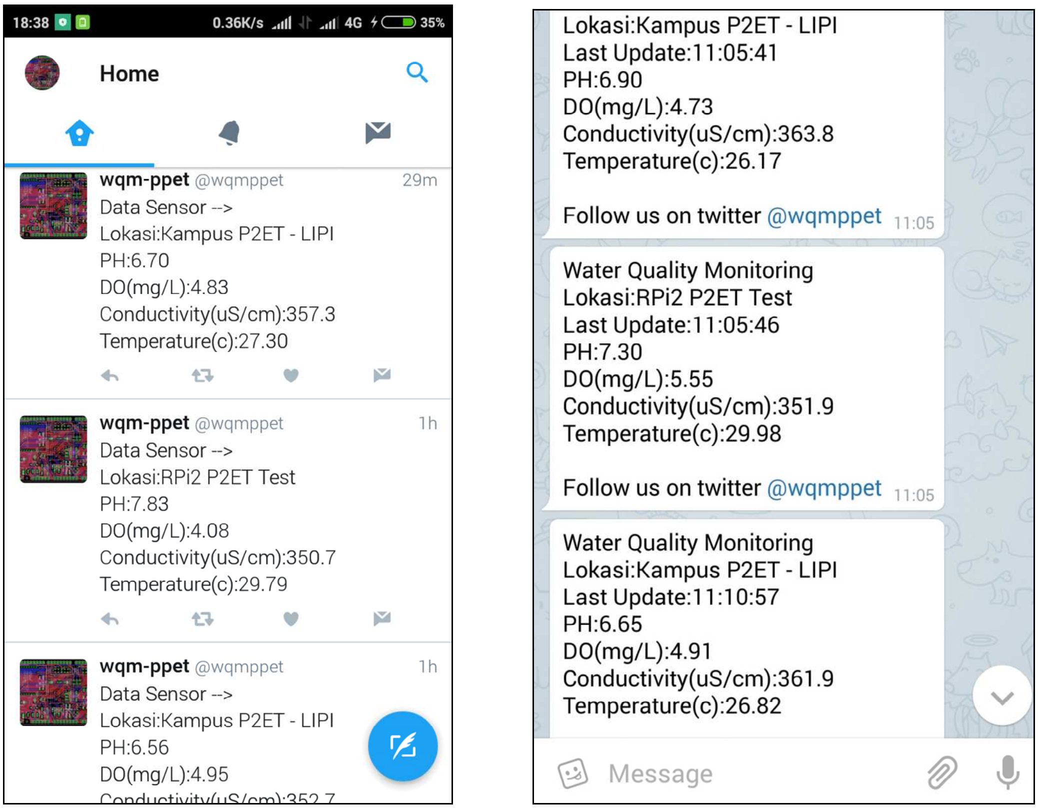

Fig. 13 Notifications of data with Twitter and Telegram Messenger application

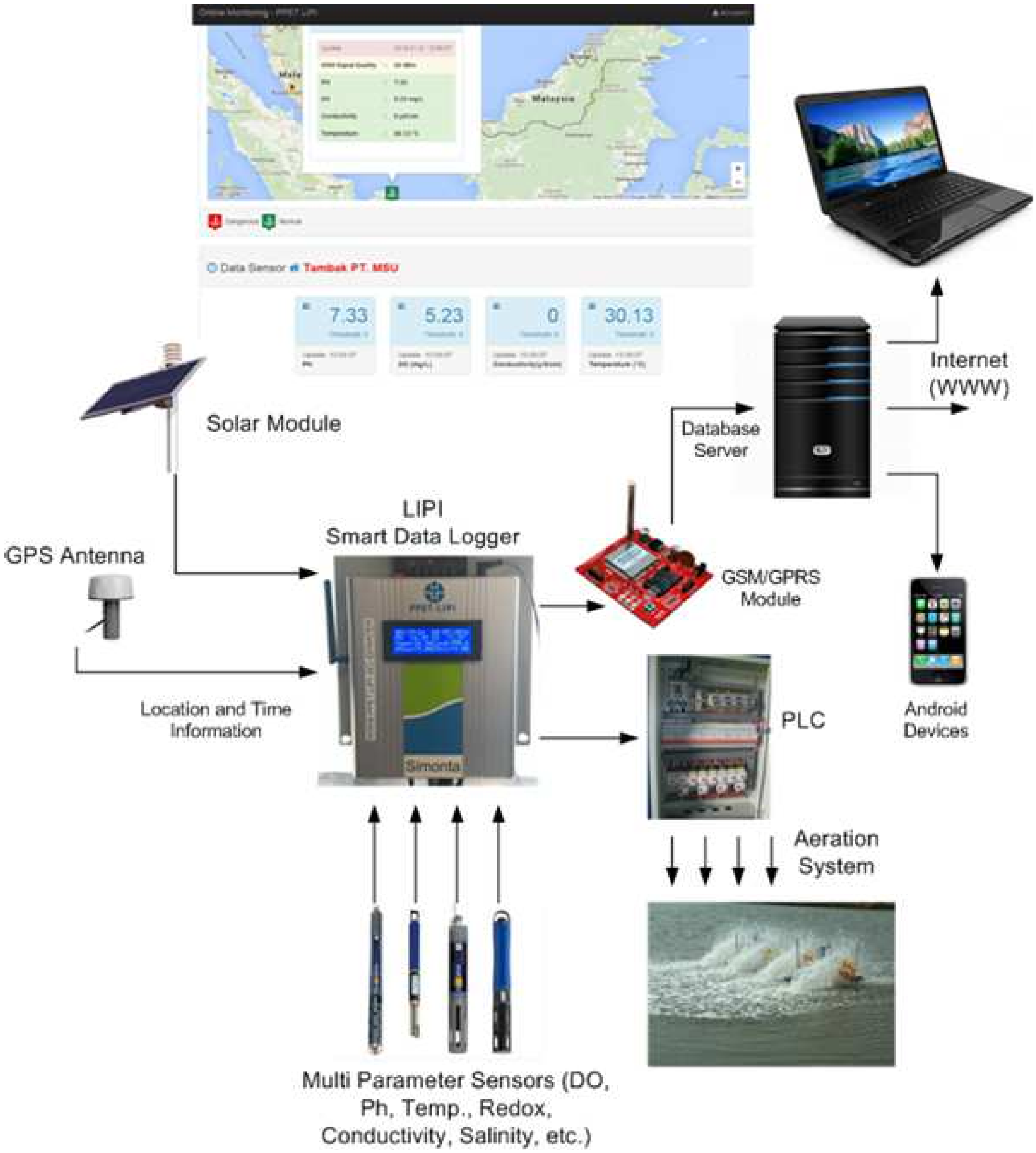

Fig. 14 Water quality monitoring in shrimp aquaculture

IV. CONCLUSION

In this paper, the design and realization of an online monitoring system for water quality network based on WSN incorporating an automatic aeration system have been described. This system has been implemented to monitor the parameters DO, pH and temperature in one of the centers of shrimp aquaculture. With the use of automatic aeration system, the value of the DO was maintained above 5 mg / L. On the other hand, the data collected from measuring sensors in each cultivation can be seen online via the website (using a laptop, PC or other mobile devices). This system has been in operation in improving the management of water quality and reducing energy from the use of paddle wheel aerators in shrimp aquaculture. The integrated system is currently under further development using the technology to replace the Arduino microcontroller with other low-cost devices such as the Raspberry Pi board. In the future, it is expected this kind of an online monitoring system can be applied in all shrimp aquaculture centers in Indonesia. The water quality data collected from each of the cultivation centers can then be integrated with other information such as water resources, businesses, and geographic information so that the database will serve as a support tool for the management in making the decision to the aquaculture industry.

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